PATENT SPECIFICATION

DRAWINGS ATTACHED

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Int. Cl.:—G 08 c//F 02 f

COMPLETE SPECIFICATION

Fuel Injection Systems for Internal Combustion Engines

We, Associated Engineering Limited, a British Company of 60, Kenilworth Road, Leamington Spa, Warwickshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to fuel injection systems for internal combustion engines.

The present invention consists in a fuel injection system for internal combustion engines comprising at least one electromagnetically operated fuel injection valve and a control pulse generator circuit producing electrical pulses for energizing said at least one injection valve, so that the valve or a valve is opened for a period depending on the duration of each of the pulses to pass fuel to the engine, said control pulse generator circuit including a timing circuit for controlling the duration of said pulses, wherein said timing circuit comprises only components having values which are invariable during the operation of the system, and said timing circuit is fed with at least one variable voltage which varies as a function of at least one parameter of engine operation to control the duration of the output pulses fed to energise said at least one injection valve.

Preferably two variable voltages are fed to the timing circuit to control the duration of the output pulses produced.

One of the variable voltages fed to the timing circuit may be derived from a computer circuit which is independent of the control pulse generator circuit, and which comprises a plurality of variable resistance devices connected across a voltage supply, at least some of said variable resistance devices respectively varying in response to different parameters of engine operation. The other variable voltage may vary as a function of the speed of rotation of the engine. The control pulse generator circuit preferably includes a monostable multivibrator having a time constant network comprising series connected elements of resistance and capacity having fixed values, or preset values which are invariable during the operation of the system. The monostable multivibrator may be triggered by pulses which are a function of the speed of rotation of the engine and be fed with the two variable voltages.

The invention will now be further described, by way of example, with reference to the accompanying drawings in which:—

Figure 1 is a block diagram of one embodiment of fuel injection system according to this invention,

Figure 2 is a block circuit diagram of one arrangement of the electrical circuits of the fuel injection system,

Figure 3 is a block circuit diagram of a further arrangement of the electrical circuits,

Figure 4 is a block circuit diagram of yet another electrical circuit arrangement,

Figure 5 is a circuit diagram of one embodiment of the main control circuit,

Figure 6 is a graph illustrating the performance of the main control circuit,

Figure 7 is a circuit diagram of one embodiment of computer circuit,

Figure 8 is a diagram of one embodiment of manifold depression transducer which may be used in the system according to this invention.

Figures 9*a*, 9*b*, 9*c*, and 9*d* are views of a pulse distributor and contact breaker which may be used in the circuit according to this

invention; Figures 9*b*, 9*c* and 9*d* being respectively sections along lines B—B, C—C, and D—D in Figure 9*a*.

Figure 10 is a diagram of one embodiment of electromagnetically operated fuel injection valve or injector, and

Figure 11 is a diagram of another embodiment of electromagnetically operated fuel injection valve or injector.

Referring to Figure 1, the fuel injection system illustrated is intended for a multicylinder internal combustion engine and comprises a fuel tank 1 from which fuel is pumped under pressure by the pump 2, through a filter to a common rail 3 supplying fuel at substantially constant pressure to individual fuel injection valves, one of which is shown at 4. Although only one fuel injector is shown, a separate injection valve is provided for each cylinder, either mounted in the inlet manifold 5 of the engine as shown, or in the case of direct injection using higher pressures, in the cylinder head or cylinder. A return pipe 6 from the common rail 3 by-passes fuel back to the tank 1 through a relief valve 7 which determines the actual pressure in the rail 3.

Since the injection valves 4 are supplied with fuel at substantially constant pressure, a periodic activation of an injection valve for a time duration dependent upon engine operating conditions will meter the fuel supplied to the engine through each injection valve. Each valve is energised by a current pulse of predetermined duration, which pulse is derived from the main control unit 8 and allocated by the distributor 9 according to the firing sequence of the engine. A quantity of fuel proportional to the electrical pulse duration is delivered in an atomised form into the cylinder through the open inlet valve, or directly into the combustion chamber in the case of the high pressure application at a predetermined point in the engine cycle.

The duration of the pulses fed from the distributor is controlled by the main control unit 8 and the computer 10. The unit 8 is triggered from a contact breaker assembly 11 mounted in the distributor housing and operating at the firing frequency of the engine.

The computer 10 is fed with information supplied by a number of transducers 12*a* to 12*f* each responsive to one or more conditions of engine operation. In this embodiment the individual transducers are arranged to sense the following conditions of engine operation:—

Transducer 12*a*—Manifold pressure
Transducer 12*b*—Engine water jacket temperature
Transducer 12*c*—Full throttle enrichment
Transducer 12*d*—Idling enrichment
Transducer 12*e*—Barometric pressure and ambient temperature
Transducer 12*f*—Acceleration effects (only employed in some cases).

In operation, the driver primarily controls a valve 13, located in the induction manifold from a conventional throttle pedal which in turn influences the behaviour of the transient transducers in response to the engine operation, and hence the exact fuel quantity is computed by the system to satisfy the required operating condition.

Referring now to Figure 2, which is a block circuit diagram of one arrangement for the electrical circuits of the system, the trigger signal produced from the contact break 11 in the distributor is fed through the differentiating circuit 20 directly to the control pulse generator 21 to control the start of the control pulse. The differentiated signal is also fed into the auxiliary pulse generator 22 to obtain a signal of suitable form for feeding the discriminator 23 which produces a voltage output which is a function of incoming pulse frequency and hence of engine speed. This latter voltage is fed to the control pulse generator 21 as a control signal and varies the duration of the output pulses from the control pulse generator according to a pre-arranged characteristic which in this embodiment is also a function of the other voltage input control signal fed to the control pulse generator from the computer 10. As has been explained with reference to Figure 1, this latter signal is a function of the following parameters of engine operation:— manifold depression, temperature, barometric pressure, acceleration, idling and throttling, in accordance with the varying signals produced by the transducers 12*a* to 12*f*.

The output from the control pulse generator 21 is therefore a train of pulses the frequency of which varies with the trigger pulse frequency and the pulse duration of which varies with the amplitudes of the control voltages applied thereto.

The pulse from the differentiating circuit 20 is also fed to a fixed length pulse generator 24, and the output pulses from the control pulse generator 21 and the fixed length pulse generator 24 are respectively amplified in the amplifiers 25 and 26 and are then added together to produce the output pulse train which is applied through the distributor 9 to control the electromagnetically operated fuel injection valves 4. As can be seen from Figure 2, the negative going output pulses fed to the distributor 9 are of a stepped character having an initial portion of greater amplitude than the remainder of the pulse. This stepped pulse form helps to produce the rapid electromagnetic operation of the injector which is essential to obtain satisfactory high speed performance of an engine.

Figure 3 shows a modified circuit arrangement wherein the transducer 12*f* producing a signal representing acceleration, is omitted and is replaced by a differentiating circuit 12*g* producing a signal which is the first derivative of

manifold depression. Apart from this modification, the circuit is the same as Figure 2.

In the circuit arrangement of Figure 4, similar parameters are employed in the computer to those employed in the circuit of Figure 3. In this embodiment however the auxiliary pulse generator 22 is omitted and the discriminator 23 is fed from the pulse produced in the control pulse generator 21. The output voltage from the discriminator 23 is fed as a variable voltage into the control pulse generator 21.

Referring now to Figure 5, this is a circuit diagram of one embodiment of the main control unit 8 as employed in the arrangement of Figure 2. The control pulse generator 21 is a monostable multivibrator employing transistors TR3 and TR4, and incorporates a time constant circuit comprising the series connected capacitor C1 and resistors R1, R2. The resistor R2 shown as preset is only adjusted during initial setting up of a system to suit the characteristics of a particular engine and thereafter is not adjusted, or may be replaced by a fixed resistor of suitable value. This multivibrator circuit is fed with pulses from the distributor 9 which are a function of the engine speed and which are derived from terminal T1 through the differentiating circuit 20. The variable output voltage from the computer 10 is fed to the multivibrator via terminal T3 and amplifier transistor TR2. A further input voltage to the multivibrator which is a function of engine speed is derived from the discriminator 23. The voltages from the computer 10 and discriminator 23 are respectively applied to the points X and Y at opposite ends of the time constant circuit of the multivibrator.

The time for one complete cycle of operation of the multivibrator i.e. the pulse duration, is primarily dependent upon the charging time of the capacitor C1 through the resistors R1, R2 to a potential V1 when the potential difference is V1+V2. The transistor TR3 is held in the "off" condition whilst the other transistor TR4 is held in the "on" condition. When the transistor TR3 is suddenly turned on by a differentiated trigger pulse from the distributor, the base of transistor TR4 is pulled positive by an amount approximately equal to V1. Transistor TR4 is turned off and its collector swings negative this swing being fed back to transistor TR3. This feedback keeps the transistor TR3 in the "on" condition after the trigger pulse has disappeared. The negative swing at the collector of the transistor TR4 is used as the output pulse and this transistor will stay in the "off" condition until capacitor C1 is charged to a potential slightly negative with respect to earth. The unit will then return very rapidly to its original condition and will remain in this condition until the next triggering pulse is received.

The auxiliary pulse generator 22 comprising transistors TR7 and TR8 and the fixed length pulse generator comprising transistors TR9 and TR10 are generally similar to the main pulse generator 21 and will not be described in detail. Their output is synchronised with engine speed but their pulse duration is not variable. The auxiliary pulse generator 22 produces constant amplitude pulses the leading edges of which coincide with the leading edges of the pulse from the main control pulse generator 21 and which are used to drive the discriminator 23. The pulse width can be preset between desired limits, for example between 1.5 ms. and 2.7 ms., by means of RV1. The fixed length pulse generator 24 generates a relatively short duration large amplitude pulse which added to the pulse from the main pulse generator 21 to produce the initiating large amplitude current drive at the beginning of the pulses fed to the fuel injection valves. The pulses from this circuit can also be preset between desired limits, for example between 0.25 ms. and 0.7 ms.

The discriminator comprising transistors TR5 and TR6 is supplied with a constant amplitude pulse from the generator 22. The output from the discriminator is a positive going pulse, the amplitude of which is a function of engine speed. The discriminator gain is controlled by RV2. This pulse represents voltage V2 applied to the control pulse generator 21 at point Y.

The power amplifier 25 comprising transistors TR15, TR16 and TR17 is fed from the control pulse generator 21 and will produce, for example, on demand a maximum pulse of 3 ms. duration, 5 amps amplitude at a maximum frequency of 300 c/s. The power amplifier 26 comprising transistors TR11, TR12 and TR13 is fed from the fixed length pulse generator 24 and will produce on demand a pulse of 0.7 ms. duration, 25 amps at a maximum frequency of 300 c/s. This constitutes the high amplitude initial portion of the stepped pulses fed to actuate the injection valves.

The output pulses from the two amplifiers 25 and 26 are combined to produce the stepped pulses which are applied to the distributor via terminal T2, and from the distributor to the fuel injection valves. The network N incorporating selector switch SW1 enables the output pulse to be set up correctly, for any particular type of engine and may be replaced by a suitable fixed resistor or resistors once setting up is achieved.

Figure 6 is a graph illustrating the performance of the main control unit. The output pulse width is a function of the output from the computer and of the trigger frequency which in turn is a function of engine speed. The curves show the changes in pulse width applied to the solenoids with changes in engine speed (trigger frequency). The gain of

discriminator 23, which can be varied by RV2, is represented by A and curves in full lines are shown for maximum and minimum values of A with maximum values of Tpc (which represents the width of the pulses fed to the discriminator from the auxiliary pulse generator 22 and which can be varied by RV1) and curves in broken lines are shown for maximum and minimum values of A with minimum values of Tpc. Four sets of such curves are shown for different outputs from the computer. The controls RV1 and RV2 are preset to suit the parameters of the engine with which the system is operating.

One embodiment of the computer will now be described with reference to Figure 7. As illustrated this circuit comprises a plurality of variable resistance devices connected in a chain across a stabilised voltage supply. These resistance devices vary in response to the following parameters of engine operation:

VR1 —Barometric pressure and ambient temperature correction
VR5 —Water temperature thermistor
VR7 —Acceleration transducer
VR9 —Idling enrichment
VR10—Manifold pressure transducer
VR12—Power correction

The resistors VR2, VR8 and VR11 serve as trimming resistors, VR3 is a ballast resistor, whilst resistors VR4 and VR6 are shunts.

The computer is essentially an analogue voltage computer, using as input data, signals from a number of transducers and producing as an output a voltage level which is acceptable to the main control unit 21 which level can be expressed as f(P, T°, Pa, ω, I, T^1). It is now proposed to describe the general action of individual data units, in the order of the function expression.

(I) f(P) Manifold pressure

The data of f(P) may be taken from a piston, bellows or diaphragm assembly used to urge a suitably coupled potentiometer.

(II) f(T°) Water manifold temperature

The data can be derived from a thermistor or similar temperature sensitive device.

(III) f(Pa) Barometric pressure and ambient temperature

The necessary data can be obtained from a temperature and pressure sensitive capsule coupled to a potentiometric device.

IV) f(W) Acceleration

This data may be taken from a diaphragm type transducer responsive to rate of change of f(P).

(V) f(I) Idling

Idling enrichment is produced by a preset control actuated upon closing of the throttle.

(VI) f(T_1) Throttle

Modification of mixture strength towards the full throttle condition may be obtained by a potentiometer controlled by the throttle mechanism.

Referring now to Figure 8 there is shown an embodiment of manifold pressure transducer which may be employed in the system according to this invention and which is adapted to be connected to the engine manifold on the downstream side of the throttle control valve. The transducer comprises a two-part casing 30 having an inlet 31 for connection to the manifold and which communicates with a passage 32 in which slides a plunger 33. The plunger is formed with a housing 34 at one end which serves as a clamp for one edge of a rolling bellows 35 whose other edge is clamped between the two parts of the casing 30. The housing also carries a rod 36 which is connected to the slider (not shown) of a variable resistor 37 which has its resistance track formed on the internal surface of its cylindrical body. The slider moves over this resistance track which constitutes, for example, the variable resistor VR10 of Figure 7. In operation variation in manifold pressure will cause the plunger 33 to slide backwards and forwards in the passage 32, so varying the position of the slider on the resistor.

Referring now to Figures 9*a*, 9*b*, 9*c*, and 9*d*, the distributor and contact breaker comprises a casing 40 through which extends a shaft 41 driven by the engine and provided with a cam portion 42 operating a make-and-break contact 43. This portion constitutes the contact breaker 11 of Figure 1, which produces the input pulses fed to the main control unit 8 (terminal T1 on Figure 5). The driving shaft 41 also carries a metal cup shaped member 44 having an isolated segment 45 which makes contact with a central brush 46 mounted in the cover 48 of the distributor. A plurality of brushes 47 are also arranged radially in the cover at equal angular spacings, six being shown in the present embodiment which is intended for use with a six-cylinder engine. The central brush 46 is connected to the output from the main control unit 8 (terminal T2 of Figure 5) and successively feeds pulses from the main control unit to operate the different electromagnetic injection valves as the cup rotates to connect the segment 45 to each of the radial brushes 47 in turn. It will be seen that the segment 45 is of such a radial extent that it only contacts one of the radial brushes 47 at any one time. Spring clips 49 serve to retain the cover 48 in position.

Figure 10 is a diagram, in cross-section, of one embodiment of electromagnetically operated fuel injection valve. This injector comprises a body 73 containing a solenoid coil 71 on a core 74. Armature 72 is connected to pintle needle 78 extending through the bore of the solenoid core. The operating coil 71 under the condition of current flow forms an area of high magnetic flux intensity across the two gaps between the armature 72 and the body 73 and core 74, thus urging the arma-

ture into contact with the pole pieces 73*a* and 74*a*. The armature is moved into this contact position against the force of a high rate spring 75. In this position the valve 79 is open and the inner sp ring 76 is relieved of some pretension whilst the centre member 77 is thus free to deflect under the force exerted by the fuel pressure on the pintle needle 78, as it flows through the bore in core 74. Thus whilst under the influence of current the injector assembly works as a normal pintle nozzle. When the current supply is interrupted the armature 72 is pulled away from the pole pieces 73*a*, 74*a* by spring 75 and delivery of fuel ceases as the pintle needle 78 closes valve 79. When the armature 72 is in contact with the pole pieces 73*a* an air gap remains between the inner land of the armature and the pole pieces 74*a* of the core 74.

This type of injector is also arranged to work on a stepped pulse waveform as herein described.

Referring now to Figure 11, this embodiment of injector basically comprises a body 62 containing a solenoid coil 51 mounted on a core 54, and an armature 52 as well as discharge nozzles 82. A current applied to the solenoid winding 51 produces an area of high magnetic flux density across the two gaps formed between the armature 52 and the pole pieces 53*a* and 53*b* of the main solenoid core 54. This magnetic force acts on the armature 52 to draw the seal 80, made for example of nylon, out of engagement with a seating 81 against the action of a high rate spring 56. Fuel now flows to the small convergent discharge nozzles 82 formed in plate 61 attached to the valve body 62. The fuel escapes from the small nozzle holes with high velocity. Upon emergence to the part conical chamber 83 the various jets of fuel impinge upon each other and their energy is largely absorbed in atomization. By variation in the angle of the holes in nozzles 82 and by the possible addition of a centre hole the ultimate spray pattern can be adjusted at will. Conversely, when the current flow is cut off from the solenoid winding, the armature 52 returns under the influence of spring 56 to allow seal 80 to seal off the nozzles 82. Thus fuel under pressure in conduit 57 is discharged through the metering nozzles 82 in the time interval between the armature leaving its seat and returning to rest on the face of the nozzles.

The magnetic path is designed such that an operating time equivalent to half the minimum pulse duration effects a saturated condition in the material at the necked portion 58 of the armature under the influence of the initial high amplitude portion of the stepped pulse applied to energise the solenoid.

The device is so arranged that when the armature 52 is attracted the outer land 59 of the armature makes contact with the pole pieces 53*a* formed on the body 54 of the solenoid, but that a non-magnetic gap remains between the inner land 60 of the armature and the pole pieces 53*b*, thus decreasing the retentivity of the magnetic circuit.

The device is also constructed so that the lands 59, 60 of the armature 52 are not parallel to the face of the solenoid, thus increasing the effective area and providing a centring action. The spring 56 is clamped at its outer diameter to provide a higher rate effect.

Whilst particular embodiments have been described it will be understood that various modifications may be made without departing from the scope of this invention as defined by the appended claims. Thus the computer may only handle a smaller number of variable engine parameters. Also changes may be made in the construction and arrangement of the electronic circuits and fuel injection valves.

Furthermore the main control unit 8 may be triggered by other means than the contact breaker assembly 11. Thus it may be triggered by the signal produced by magnetic or capacitive pick-up means, or from an electro-optical pick-up arrangement associated with the distributor or engine flywheel.

WHAT WE CLAIM IS:—

1. A fuel injection system for internal combustion engines comprising at least one electromagnetically operated fuel injection valve and a control pulse generator circuit producing electrical pulses for energizing said at least one injection valve, so that the valve or a valve is opened for a period depending on the duration of each of the pulses to pass fuel to the engine, said control pulse generator circuit including a timing circuit for controlling the duration of said pulses, wherein said timing circuit comprises only components having values which are invariable during the operation of the system, and said timing circuit is fed with at least one variable voltage which varies as a function of at least one parameter of engine operation to control the duration of the output pulses fed to energise said at least one injection valve.

2. A system as claimed in claim 1, wherein two variable voltages are fed to the timing circuit to control the duration of the output pulses produced.

3. A fuel injection system for internal combustion engines comprising a plurality of electromagnetically operated fuel injection valves and a control pulse generator circuit producing electrical pulses for energizing said fuel injection valves so that each valve is opened for a period depending on the duration of the pulses fed to it to pass fuel to the engine and the pulses are allocated to the respective valves according to the firing sequence of the engine, said control pulse generator including a timing circuit for controlling the duration of the pulses which comprises only components having values which are in-

variable during the operation of the system and said timing circuit being fed with two variable voltages to control the duration of the output pulses fed to energise said fuel injection valves, one of said variable voltages varying as a function of one parameter of engine operation and the other variable voltage varying in dependence upon a plurality of other parameters of engine operation.

4. A system as claimed in any preceding claim, wherein a variable voltage fed to the timing circuit is derived from a computer circuit which is independent of the control pulse generator circuit, and which comprises a plurality of variable resistance devices connected across a voltage supply, at least some of said variable resistance devices respectively varying in response to different parameters of engine operation.

5. A system as claimed in claims 2 and 4 or claims 3 and 4, wherein one of said variable voltages is derived from the computer circuit and the other variable voltage varies as a function of the speed of rotation of the engine.

6. A system as claimed in any preceding claim, wherein the control pulse generator circuit includes a monostable multivibrator having a time constant network comprising series connected elements of resistance and capacity having values which are invariable during the operation of the system.

7. A system as claimed in claim 6, wherein at least one of the eelments of resistance and capacity is a preset component.

8. A system as claimed in claim 6 or 7, wherein the monostable multivibrator is triggered by pulses which are a function of the speed of rotation of the engine.

9. A system as claimed in claim 8, wherein a variable voltage fed to the monostable multivibrator is a function of engine speed and is derived from a discriminator circuit.

10. A system as claimed in claim 9, wherein the triggering pulses which are a function of the speed of rotation of the engine, are fed through an auxiliary pulse generator to the discriminator.

11. A system as claimed in claim 9, wherein the discriminator is fed with pulses produced from the monostable multivibrator which is itself triggered by pulses which are a function of the speed of rotation of the engine.

12. A system as claimed in any preceding claim, wherein a separate fuel injection valve is provided for each cylinder of the engine with which the system is to be used.

13. A system as claimed in any preceding claim, wherein the fuel injection valve or valves is/are mounted in the inlet manifold of the engine.

14. A system as claimed in any preceding claim, having a plurality of fuel injection valves, and wherein the output pulses from the control pulse generator are allocated to the respective valves by a distributor device according to the firing sequence of the engine.

15. A system as claimed in claim 14, wherein the distributor is driven by the engine.

16. A system as claimed in claim 14 or 15, wherein the distributor also includes a contact breaker assembly for producing triggering pulses fed to trigger the control pulse generator.

17. A system as claimed in any preceding claim, wherein each pulse fed to energise the at least one fuel injection valve has an initial portion of greater amplitude than the remainder of the pulse so that said initial portion causes rapid energisation of the electromagnet of the fuel injection valve and hence opening of the valve, and the later portion of each pulse of a lower level is sufficient to retain the valve open, but enables rapid closing of the valve upon termination of the pulse.

18. A system as claimed in claim 17, wherein a series of pulses are produced which are of shorter duration but of greater amplitude than the output pulses from the control pulse generator and said series of pulses are mixed with said output pulses to produce the pulses each having an initial portion of greater amplitude than the remainder of the pulse.

19. A fuel injection system substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.

20. A fuel injection system as claimed in claim 19, having electrical circuits substantially as hereinbefore described with reference to Figures 2 and 5, or Figures 3 and 5, or Figure 4 of the accompanying drawings.

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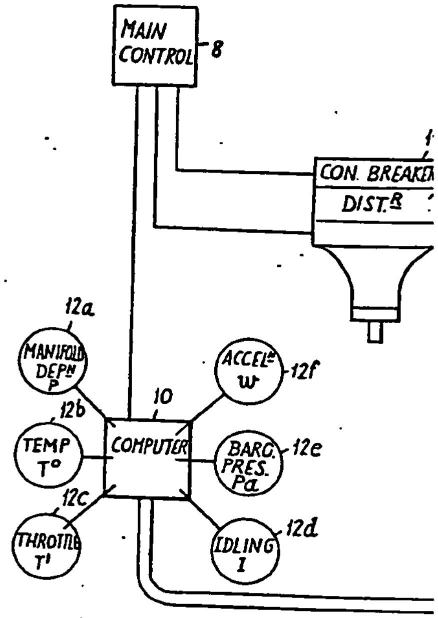
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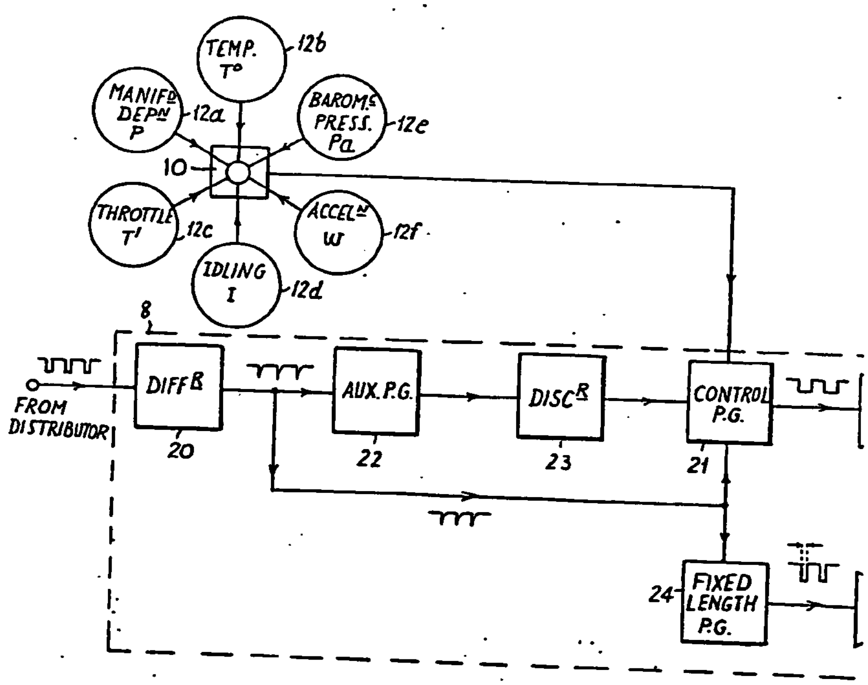
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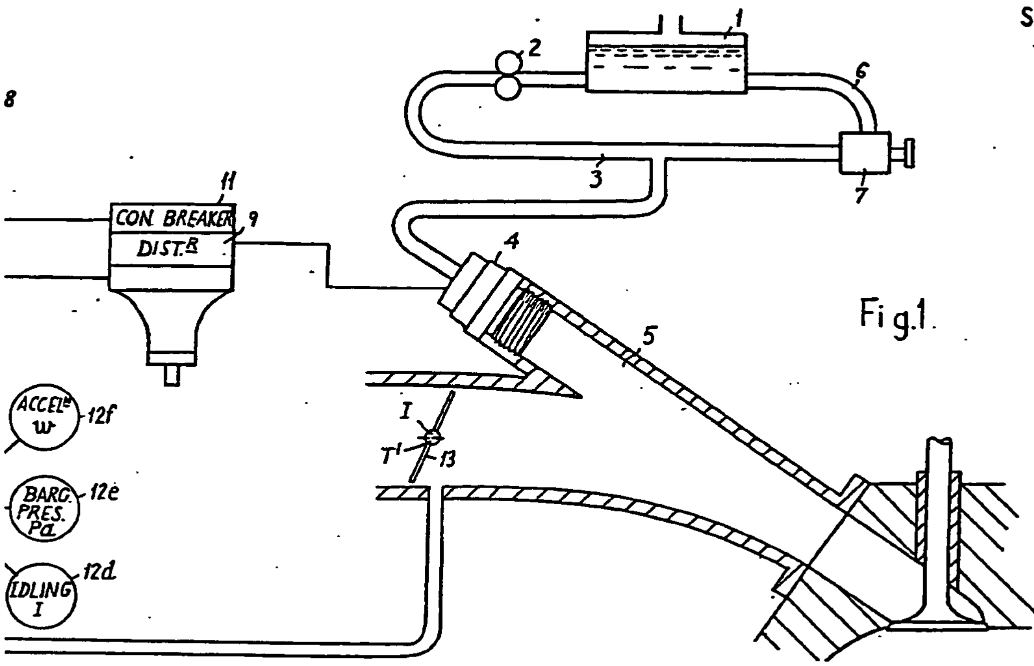
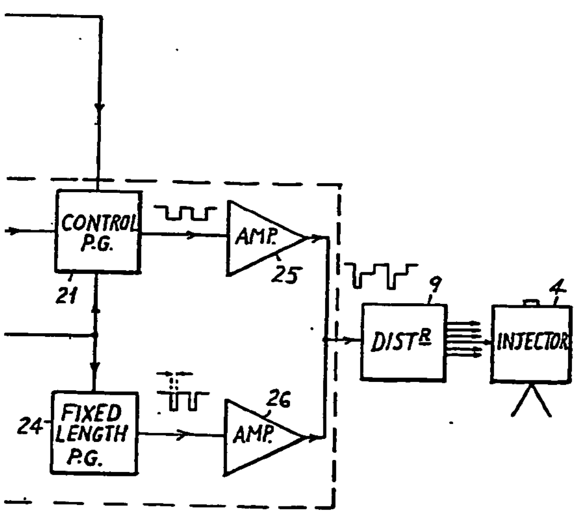


Fig.1.

Fig.2



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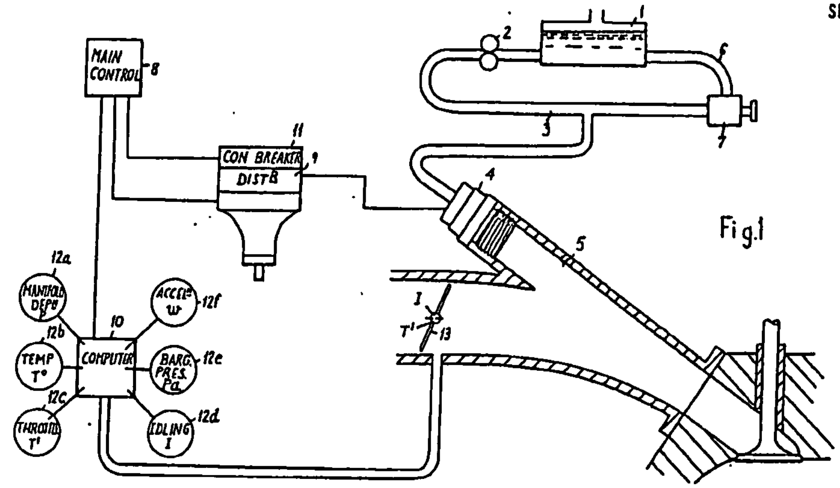


Fig.1

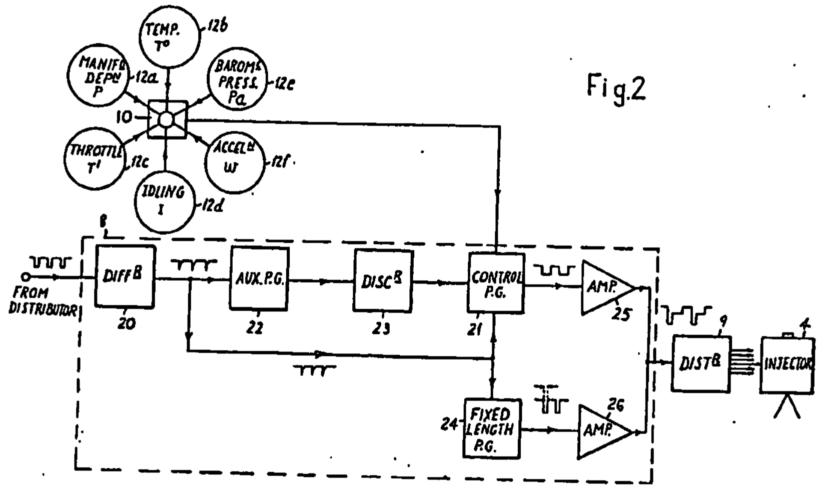
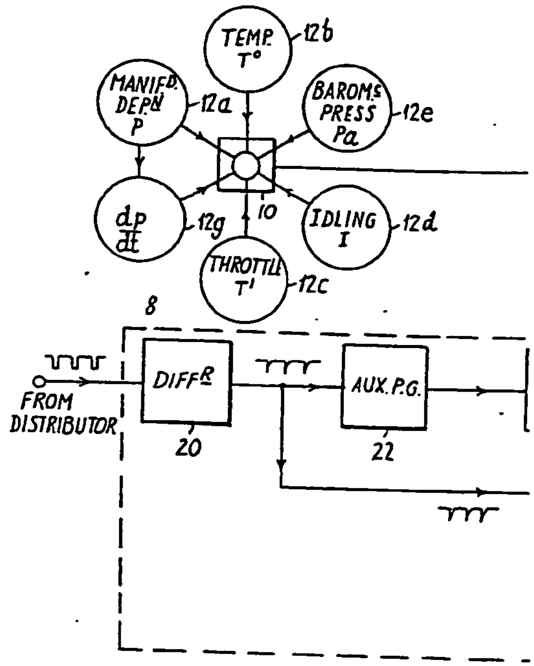


Fig.2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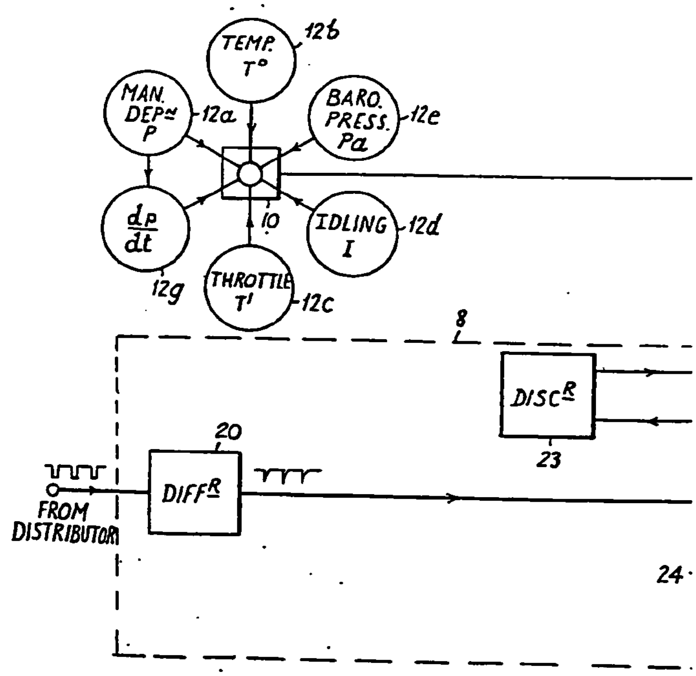
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Sheet 2

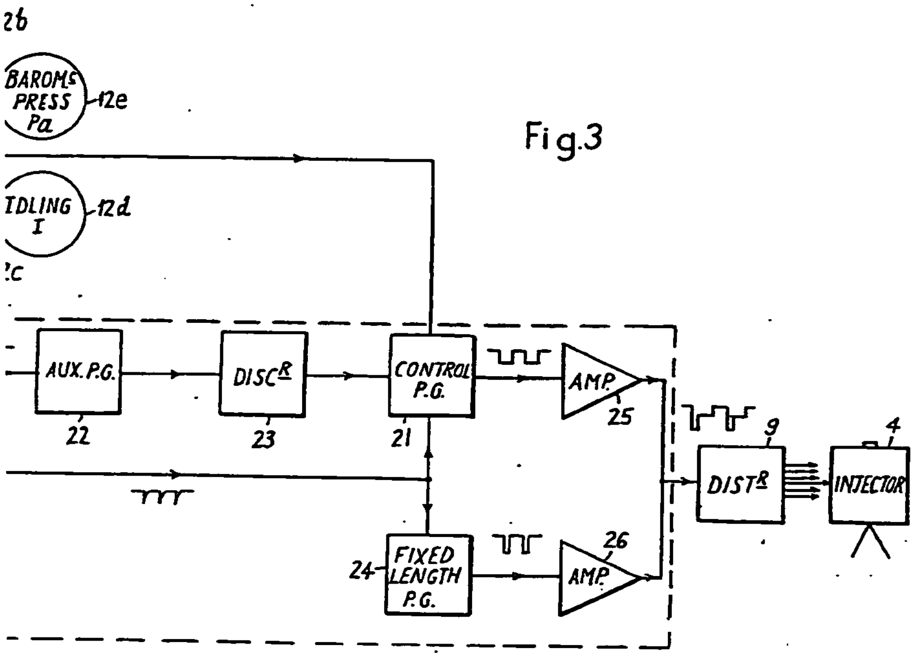

Fig.3

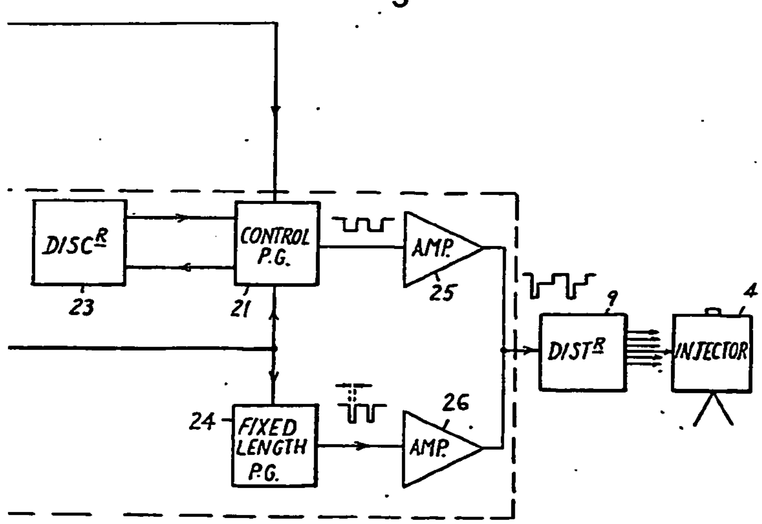

Fig.4

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Sheet 2

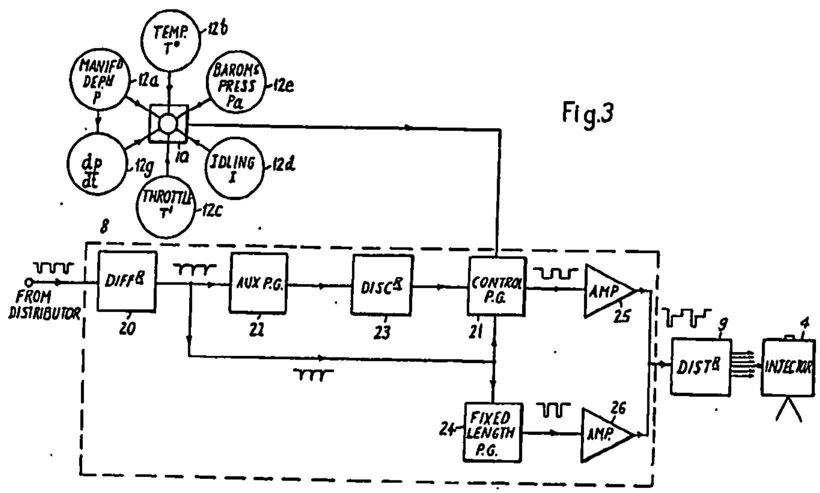

Fig.3

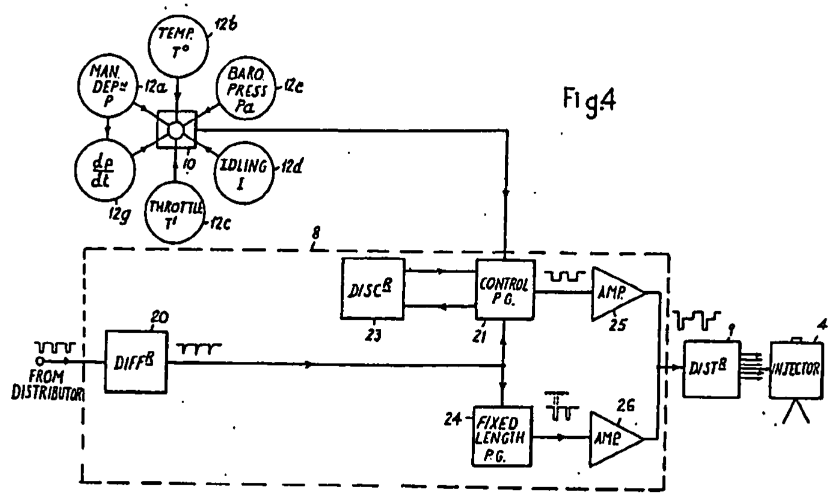

Fig.4

1038541 COMPLETE SPECIFICATION

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Sheet 3

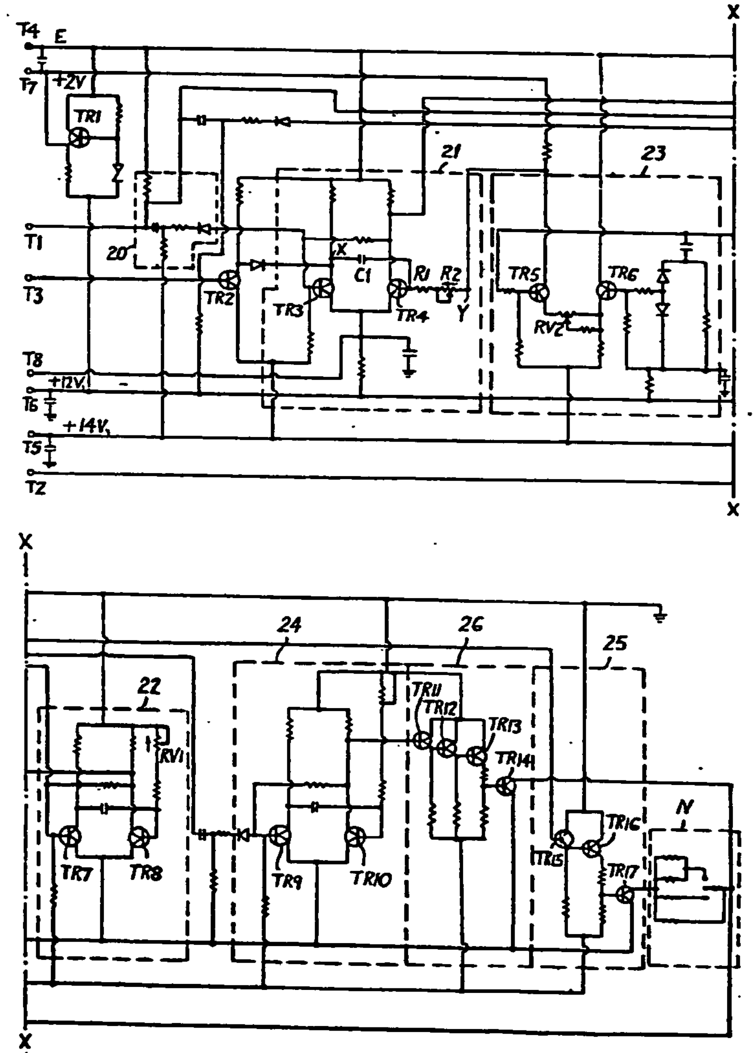


Fig.5

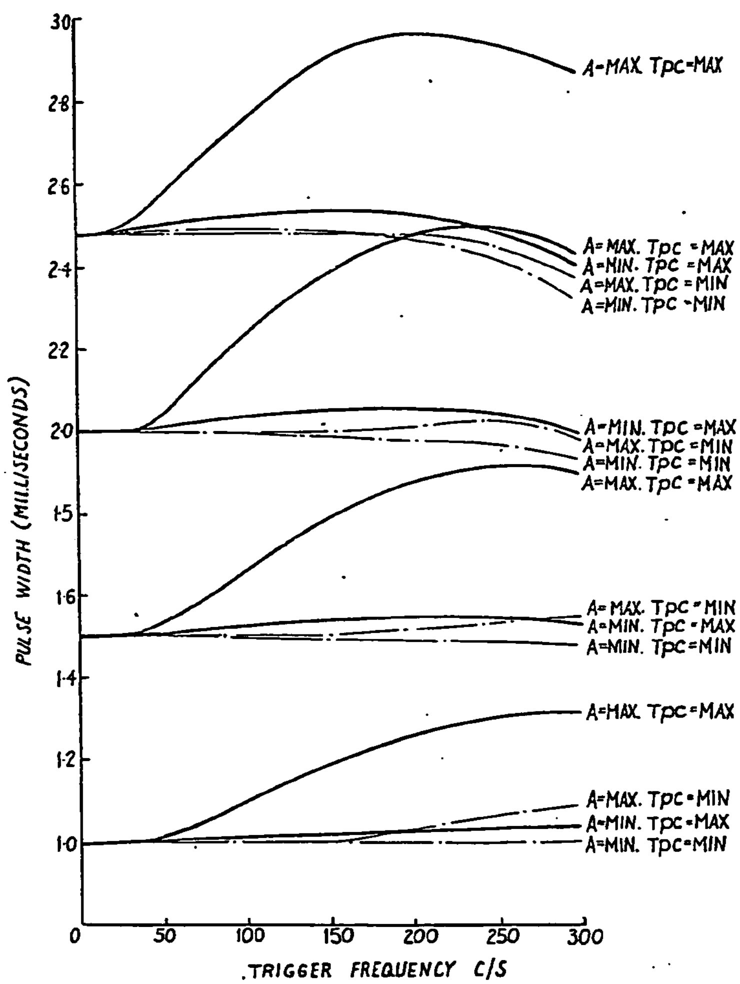

3·0
2·8
2·6
2·4
2·2
2·0
1·5
1·6
1·4
1·2
1·0
PULSE WIDTH (MILLISECONDS)
0
50
100
150
200
250
300
TRIGGER FREQUENCY C/S
A=MAX. Tpc=MAX
A=MAX. Tpc=MAX
A=MIN. Tpc=MAX
A=MAX. Tpc=MIN
A=MIN. Tpc=MIN
A=MIN. Tpc=MAX
A=MAX. Tpc=MIN
A=MIN. Tpc=MIN
A=MAX. Tpc=MAX
A=MAX. Tpc=MIN
A=MIN. Tpc=MAX
A=MIN. Tpc=MIN
A=MAX. Tpc=MAX
A=MAX. Tpc=MIN
A=MIN. Tpc=MAX
A=MIN. Tpc=MIN

Fig.6

A=MAX. Tpc=MAX

A=MAX. Tpc=MAX
A=MIN. Tpc=MAX
A=MAX. Tpc=MIN
A=MIN. Tpc=MIN

A=MIN. Tpc=MAX
A=MAX. Tpc=MIN
A=MIN. Tpc=MIN
A=MAX. Tpc=MAX

A=MAX. Tpc=MIN
A=MIN. Tpc=MAX
A=MIN. Tpc=MIN

A=MAX. Tpc=MAX

A=MAX. Tpc=MIN
A=MIN. Tpc=MAX
A=MIN. Tpc=MIN

300

Fig.7

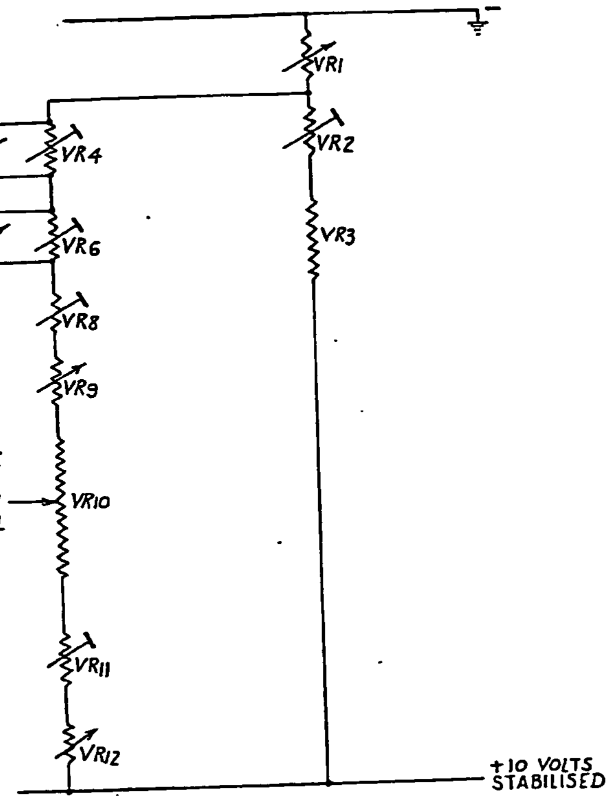
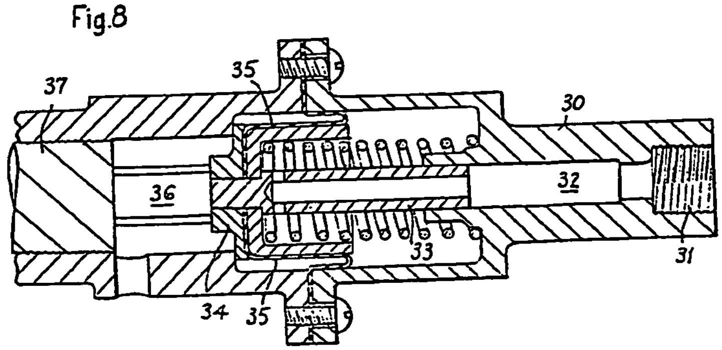


Fig.8



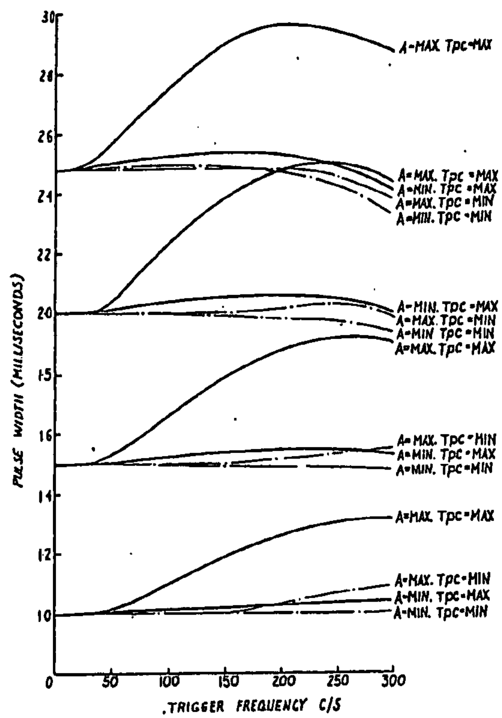


Fig.6

Fig.7

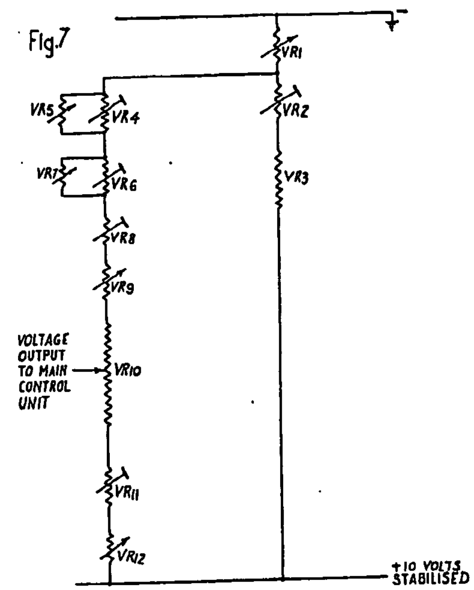


Fig.8

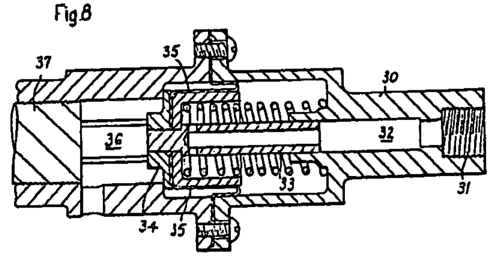


Fig.9a

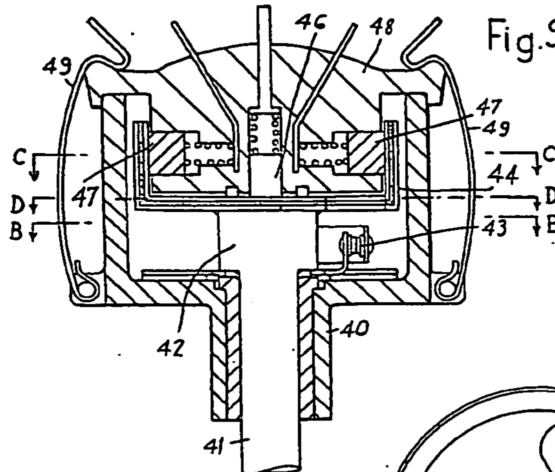


Fig.9b

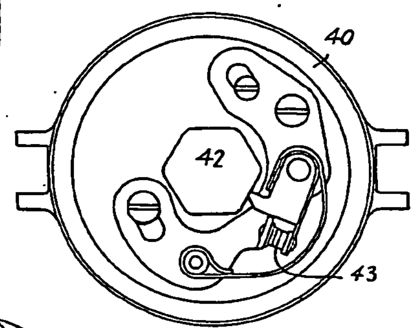


Fig.9c

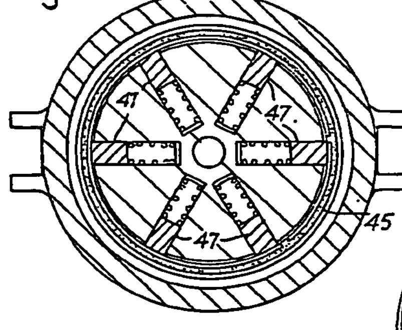
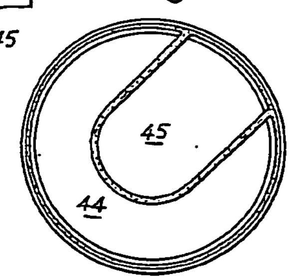


Fig.9d



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Sheets 6 & 7

Fig.10

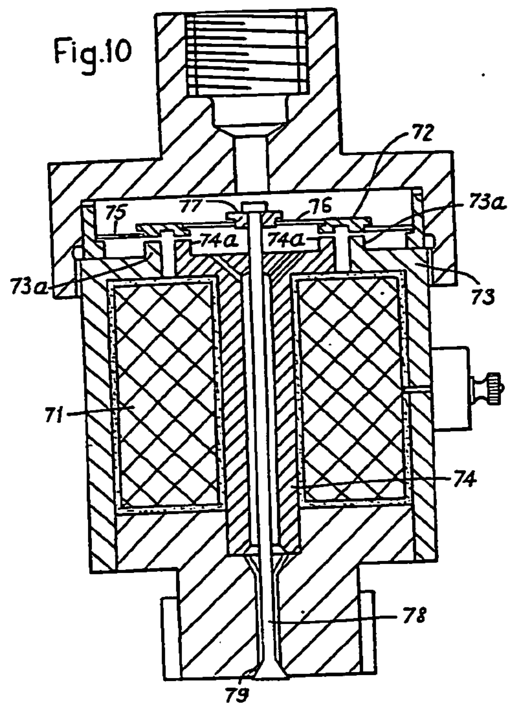


Fig.9b

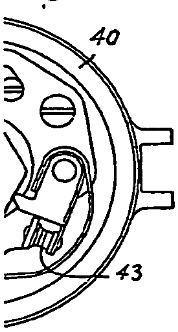


Fig.11

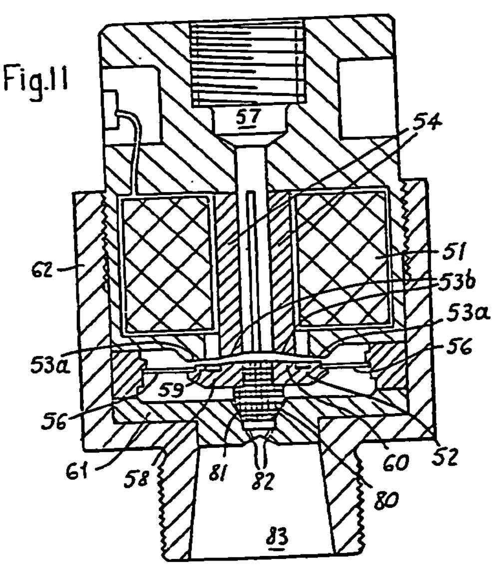
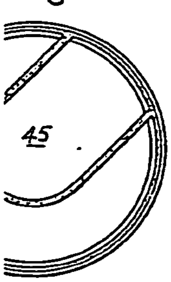


Fig.9d



1038541 COMPLETE SPECIFICATION
7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheets 6 & 7

Fig.9a

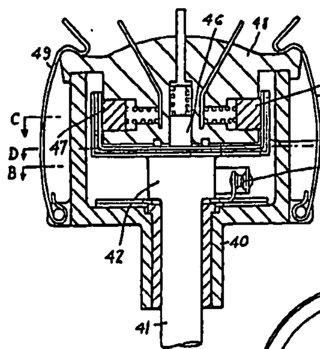


Fig.9b

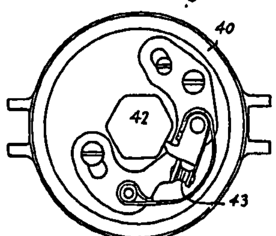


Fig.9c

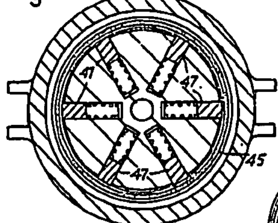


Fig.9d

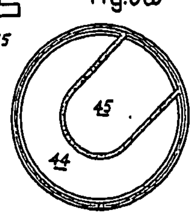


Fig.10

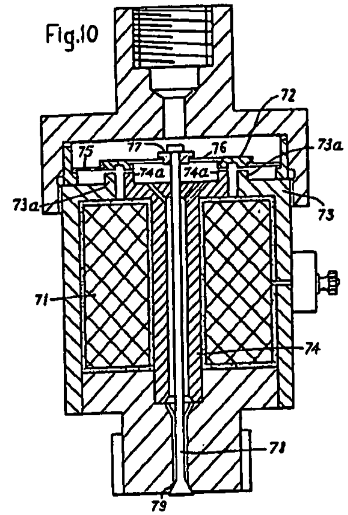


Fig.11